REMARKS

In the outstanding Office Action, the Examiner rejected claims 1, 3, 4, 6, 8-18, 20-24, 26-30, 32, 34-44, 46-50, 52-55, 57, 58, 60-72, 74-78, 80-84, 86, 88-98, 100-104, 106-109, 111, 112, 114, 116-126, 128-132, 134-138, 140, 142-152, 154-158, and 160-162. In addition, the Examiner withdrew claims 2, 5, 7, 19, 31, 33, 45, 56, 61, 73, 85, 87, 99, 110, 113, 115, 127, 139, 141, and 153 from further consideration. The Examiner also objected to the drawings and the specification.

The Examiner indicated that claims 25, 51, 79, 105, 133, and 159 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims. By this amendment, Applicant cancels claims 25, 51, 79, 105, 133, and 159, without prejudice or disclaimer, amends claims 1, 29, 55, 83, 109, and 137, and adds new claims 163-174. With entry of this amendment, claims 1, 3, 4, 6, 8-18, 20-30, 32, 34-44, 46-55, 57, 58, 60-72, 74-84, 86, 88-98, 100-109, 111, 112, 114, 116-126, 128-138, 140, 142-152, and 154-174 are pending and under consideration.

Objections to the drawings

In the Examiner's objections to the drawings, the Examiner indicated that the positive lens group and the negative lens group must be shown in the drawings. Office Action at section 5, page 4. Applicant respectfully traverses this objection.

Applicant respectfully asserts that, in the general optics field and in this application, the term "lens group" does not limit the number of lenses which comprise the lens group to more than one lens. In other words, one skilled in the art of optics

would understand the meaning of "lens group" to comprise not only multiple lenses but also a single lens. Therefore, the recitation of either a "positive lens group" or a "negative lens group" in the claims of the instant application includes an embodiment comprising a single positive lens or a single negative lens, respectively.

Applicant provides the following exemplary document to support this assertion. For example, please refer to, inter alia, United States Patent Publication No. US 2004/0179273 A1. As is supported by at least Fig. 1, the abstract, claim 1, and paragraphs [0034] to [0035], Applicant respectfully notes that each of the second and third lens groups recited therein consist of a single lens. See, e.g., Fig. 1, items "3" and "4."

The drawings of this application show one positive lens and one negative lens as one embodiment of a positive lens group and a negative lens group, respectively. Thus, Applicant asserts that the drawings properly illustrate certain embodiments of the positive lens group and the negative lens group as recited in the claims. As such, Applicant respectfully submits that correction of the drawings is not necessary and, therefore, the Examiner's objection to the drawings should be withdrawn.

Objections to the specification

In the Examiner's objection to the specification, the Examiner indicated that the title of the invention is neither precise nor descriptive. Office Action at section 6.a., page 4. In response, Applicant amends the title of the invention as is shown in the attached marked-up specification.

In addition, the Examiner indicated that the specification contains many numbers which do not clearly provide a relationship to anything else in the application. Office Action at section 6. b., page 5. In response, Applicant amends the specification to modify and more fully explain the numbers in question.

In view of these amendments to the specification, Applicant respectfully requests that the outstanding objections to the specification be withdrawn.

Rejections under 35 U.S.C. § 112, first paragraph and second paragraph

The Examiner rejected claims 10-11, 15-18, 36-37, 41-44, 64-65, 69-72, 90-91, 95-98, 118-119, 123-126, 144-145, and 149-152 under 35 U.S.C. § 112, first paragraph. Office Action at section 7, page 5. In particular, the Examiner stated that a "positive lens group" and a "negative lens group" recited in the claims are not described in the specification.

Applicants traverse the rejection under 35 U.S.C. § 112, first paragraph, and respectfully submit that the specification and drawings, as filed, would enable one of ordinary skill in the art to make and use the claimed positive lens group and negative lens group. As explained above and as clearly shown in the specification and drawings, the claimed lens group includes one or more lenses. At least because the specification and drawings describe a lens group embodiment having one lens, the specification and drawings enable the claimed invention.

The Examiner additionally rejected claims 10-11, 15-18, 36-37, 41-44, 64-65, 69-72, 90-91, 95-98, 118-119, 123-126, 144-145, and 149-152 under 35 U.S.C. § 112, second paragraph. Office Action at section 8, page 6. The Examiner indicated that

since no (lens) group has been defined or shown in the drawings at all, the claims are confusing and unclear. Applicants traverse the rejection under 35 U.S.C. § 112, second paragraph, and respectfully submit that the pending claims are clear and definite. In view of the knowledge in the optical field, the specification, and the drawings, the terms "positive lens group" and "negative lens group" as recited in the pending claims would be clear and definite to one of ordinary skill. As explained above, each claimed "lens group" includes one or more lenses. Therefore, one of ordinary skill in the art would understand the scope of the pending claims.

Rejections under 35 U.S.C. §§ 102 and 103

The Examiner rejected claims 1, 6, 8-9, 20-21, 55, 57-58, 60, 62-63, 74-75, 109, 111-112, 114, 116-117, 128-129, 137-138, 140, 142-143, and 154-155 under 35 U.S.C. § 102(e) as allegedly anticipated by United States Patent No. 6,243,350 to Knight et al. ("Knight"). Office Action at section 9, page 6. In addition, the Examiner rejected claims 3-4, 29-30, 32, 34-35, 46-47, 83-84, 86, 88-89, and 100-101 under 35 U.S.C. § 103(a) as being unpatentable over Knight in view of United States Patent No. 6,621,787 to Lee et al. ("Lee"). Office Action at section 33, pages 9-10. Furthermore, the Examiner rejected claims 12-14, 38-40, 66-68, 92-94, 120-122, and 146-148 under 35 U.S.C. § 103(a) as being unpatentable over Knight and Lee in further view of United States Patent No. 6,091,549 to McDonald et al. ("McDonald"). Office Action at section 42, pages 11-12. Additionally, the Examiner rejected claims 22-24, 48-50, 76-78, 102-104, 130-132, and 156-158 under 35 U.S.C. § 103(a) as being unpatentable over Knight and Lee in further view of United States Patent No. 6,054,503 to Ichikawa et al. ("Ichikawa").

Office Action at section 45, page 13. Lastly, the Examiner rejected claims 26-28, 52-54, 80-82, 106-108, 134-136, and 160-162 under 35 U.S.C. § 103(a) as being unpatentable over Knight and Lee in further view of United States Patent No. 6,594,205 to Aarts et al. ("Aarts"). Office Action at section 49, pages 14-15.

The Examiner indicated that claims 25, 51, 79, 105, 133, and 159 would be allowable if rewritten to include all of the elements of the base claim and any intervening claims. Office Action at section 54, page 16. Furthermore, the Examiner stated:

> the cited references taken individually or in combination fails to particularly disclose an apparatus which includes an optical head which includes a converging optical system that has [an] optical element "having an internal transmission rate of 85% or more at a portion having a thickness of 3 mm for the light flux having a[n] oscillation wavelength of the light source."

Office Action at section 54, page 16.

Applicant hereby amends claim 1 to incorporate **only** the limitation recited in claim 25, which corresponds to the converging optical system having an optical element "having an internal transmission rate of 85% or more at a portion having a thickness of 3 mm for the light flux having an oscillation wavelength of the light source" that was deemed allowable by the Examiner. That is, even though claim 25 depends from claim 22, the limitation recited in claim 22 does not appear in amended claim 1. However, in view of the Examiner's reasons for allowance of claim 25, Applicant believes that amended claim 1 is nevertheless allowable for the same reasons given by the Examiner relating to claim 25. In addition, Applicant cancels claim 25. Accordingly, Applicant respectfully submits that claim 1 is allowable over the cited art. In addition, Applicant

respectfully asserts that claims 3, 4, 6, 8-18, and 20-27 are in condition for allowance as well.

Further, in a similar manner to the amendment to claim 1, Applicant amends each of claims 29, 55, 83, 109, and 137 to incorporate **only** the limitation of each of claims 51, 79, 105, 133, and 159, respectively. Applicant also correspondingly cancels claims 51, 79, 105, 133, and 159. Therefore, Applicant respectfully asserts that claims 29, 55, 83, 109, and 137 should be allowable over the cited art. In addition, Applicant respectfully asserts that claims 30, 32, 34-44, 46-54, 57, 58, 60-72, 74-82, 84, 86, 88-98, 100-108, 111, 112, 114, 116-126, 128-136, 138, 140, 142-152, and 154-162 are in condition for allowance as well.

New claims 163-174

Applicant adds new claims 163-174. Claim 163 includes **only** the limitations recited in claims 1, 9, and 10 (i.e., even though claim 9 depends from claim 6, the limitation recited in claim 6 is not incorporated into amended claim 163). Similarly, claim 164 includes **only** the limitations recited in claims 1, 9, 14, and 15. Claim 165 includes **only** the limitations recited in claims 29, 35, and 36. Claim 166 includes **only** the limitations recited in claims 29, 35, 40, and 41. Claim 167 includes **only** the limitations recited in claims 55, 63, and 64. Claim 168 includes **only** the limitations recited in claims 55, 63, 68, and 69. Claim 169 includes **only** the limitations recited in claims 83, 89, and 90. Claim 170 includes **only** the limitations recited in claims 83, 89, 94, 95. Claim 171 includes **only** the limitations recited in claims 109, 117, and 118. Claim 172 includes **only** the limitations recited in claims 109, 117, 122, and 123. Claim 173

includes **only** the limitations recited in claims 137, 143, and 144. Claim 174 includes **only** the limitations recited in claims 137, 143, 148, and 149.

Applicant respectfully asserts that, as stated above in the "[r]ejections under 35 U.S.C. § 112, first paragraph and second paragraph" section of this paper, the rejections made under 35 U.S.C. § 112 to claims 10, 15, 36, 41, 64, 69, 90, 95, 118, 123, 144, and 149 should be withdrawn. Since these were the sole rejections to these claims, Applicant respectfully asserts that the similar, though not identical, new claims 163-174 are in condition for allowance pending the Examiner's further determination of allowability.

Applicant respectfully requests reconsideration and reexamination of this application and the timely allowance of the pending claims.

Please grant any extension of time required to enter this response and charge any additional required fees to Deposit Account 06-0916.

Respectfully submitted,

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Dated: November 22, 2004

By: _____
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Linda Phillips

~~OPTICAL PICK-UP APPARATUS, LIGHT CONVERGING OPTICAL SYSTEM OF OPTICAL PICK-UP APPARATUS, AND OPTICAL INFORMATION RECORDING AND REPRODUCING METHOD~~ **OPTICAL PICK-UP APPARATUS ACHIEVING HIGH NUMERICAL APERTURE, OPTICAL CONVERGING SYSTEM THEREFOR, AND RECORDING AND/OR REPRODUCING METHOD UTILIZING THEM**

BACKGROUND OF THE INVENTION

The present invention relates to an optical pick-up apparatus to record and reproduce the information onto the optical information recording medium having a plurality of information recording layers, in layer-like, and a light converging optical system of the optical pick-up apparatus, and optical information recording and reproducing method, and particularly to an optical pick-up apparatus to record or reproduce the information onto a laminated plurality of information recording layers, by using a luminous flux whose image side numerical aperture is not smaller than 1.0, using

an evanescent light, a light converging optical system of the optical pick-up apparatus, and optical information recording and reproducing method.

Recently, accompanied by putting to practical use of the short wavelength red semiconductor laser, a DVD (digital versatile disk) whose dimension is almost the same as the CD (compact disk) which is the conventional optical disk, that is, optical information recording medium, and whose capacity is largely increased and which is the high density optical disk, is developed, and put into the market, however, it is forecasted that, in near future, the higher density next generation optical disk is also comes into the market. In the optical system of the optical information recording and reproducing apparatus using such the optical disk as the medium, in order to intend to highly increase the density of the recording signal, or to reproduce the high density recording signal, it is required that the spot diameter which is light converged onto the recording medium through the light converging optical system is reduced. For such the requirement, as a solution means, the optical element using the principle of near field is proposed. The high NA of such the optical element is attained by using the evanescent light which is leaked from a solid immersion lens opposite to the

information recording surface, and for example, it is written in Japanese Tokkai No. 2000-99990.

However, when the information is recorded or reproduced to the optical information recording medium by using the evanescent light, because the evanescent light has the characteristic which rapidly attenuates corresponding to the distance, it is necessary that the information recording surface is formed on the surface of the optical information recording medium. However, a fact that the information recording surface is formed on the surface of the optical information recording medium, is that the protective layer can not be provided on the information recording surface. Accordingly, when it is used only in the hermetically shielded space, such the optical information recording medium can be used, however, for the removable optical disk such as the CD or DVD whose presupposition is that the user exchanges it by his hand, it is difficult that the information is recorded or reproduced by using the evanescent light.

Further, in order to intend to record or reproduce the high density information, the multi-layer type optical information recording medium in which the information recording layer is laminated, is also developed. When the recording or reproducing of the information is conducted onto

such the optical information recording medium, it is a problem how makes the information recording light including the evanescent light form an image onto each of information recording layers.

SUMMARY OF THE INVENTION

The present invention is attained in view of the forgoing conventional technological problem, and an object of the present invention is to provide an optical pick-up apparatus by which the high density optical information recording or reproducing can be conducted onto the multi-layer type optical information recording medium, a light converging optical system of the optical pick-up apparatus, and optical information recording or reproducing method.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view of a final optical element (almost semi spherical lens) constituting a portion of an objective lens of the present invention.

Fig. 2 is an outline structural view of an optical pick-up apparatus by which the recording or reproducing of the information can be conducted onto a multi-layer type

optical information recording medium which is an embodiment of the present invention.

Fig. 3 is an outline structural view showing an optical system according to the second embodiment.

Fig. 4 is an outline structural view showing an optical system according to the third embodiment.

Figs. 5(a) and 5(b) each is a view showing the relationship between the final optical element and diaphragm according to the fourth embodiment.

Figs. 6(a) and 6(b) each is a view showing the relationship between the objective lens and diaphragm according to the fifth embodiment.

Figs. 7(a) and 7(b) each is a view showing a light converging optical system according to the sixth embodiment.

Figs. 8(a) and 8(b) each is a view showing the light converging optical system according to the seventh embodiment.

Figs. 9(a) and 9(b) each is a view showing a light converging optical system according to the eighth embodiment.

Fig. 10 is a view showing an objective lens composition according to another embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Hereinafter, the structure to attain the above object will be explained.

~~An optical pick-up apparatus of (1)~~ A first structure of the optical-pickup apparatus of the invention is an optical pick-up apparatus which has a light source, and a light converging optical system to light converge onto any of information recording layers of the optical information recording medium having the laminated plurality of information recording layers, and in the optical pick-up apparatus in which the recording or reproducing of the information is conducted onto the optical information recording medium, because the light converging optical system records or reproduces the information onto the information recording layer by light converging the luminous flux whose image side numerical aperture is not smaller than the 1.0, onto the optical information recording layer, the high density optical information recording or reproducing can be conducted onto the optical information recording medium. In this connection, as such the light converging optical system, so called a solid immersion lens, SIL, or SIM (which will be described later), is included, but, it is not limited to this.

In the optical system of the conventional optical pick-up apparatus, it is difficult to attain more than the image side numerical aperture (NA) of 1.0. The reason will be described below. The image side numerical aperture is defined as $n \cdot \sin\theta$ (n is the refractive index of the medium of the image space, and the θ is a half angle of the maximum cone angle in the medium of the image space), however, in the optical pick-up apparatus, when the recording and reproducing of the information is conducted onto the recording medium rotating like the CD, the air layer absolutely exists between the optical system and the recording medium, and its refractive index n is 1. Further, because $-1 \leqq \sin\theta \leqq 1$, the NA is 1 at the maximum, and in the actual image formation, the NA can only have a value not larger than 1.

As described above, in the optical pick-up apparatus, on the presupposition that the air layer exists between the optical system and the optical information recording medium, when the image side numerical aperture (NA) can attain more than 1, because the spot diameter in the information recording layer can be reduced very small, the recording density of the optical information recording medium is increased, and while intending to reduce the size of the

recording medium, the larger capacity information can be recorded or reproduced. Further, in the optical information recording medium having a plurality of information recording layers, an increase of the volume recording density can be intended.

In opposition to this, in the present invention, as an example of the optical system to attain the image side numerical aperture (NA), which is not smaller than 1, a light converging optical system using the effect of the near field is provided. Herein, the providing of the light converging optical system using the effect of the near field will be described below. Fig. 1 is a sectional view of the final optical element (almost semi-spherical lens) constituting a portion of the light converging optical system of the present invention. The luminous flux incident to the almost semi-spherical lens transmits within the range of the first predetermined angle $\theta 1$, and is irradiated onto the recording medium RM. However, for the luminous flux exceeding the first predetermined angle $\theta 1$, it is totally reflected on the lower surface of the almost semi-spherical lens HL, and as the result, it is said that the luminous flux is not effectively irradiated onto the recording medium RM.

Herein, when the light is totally reflected on the lower surface of the almost semi-spherical lens HL, there is a phenomenon that the evanescent light leaks out to the recording medium RM. Such the effect is called the near field effect, and the leaked-out light is called the evanescent light E. The evanescent light E has the characteristic that, after it is emitted from the almost semi-spherical lens HL, as the distance is larger, the light exponentially attenuates. Accordingly, when the distance Δ between the lower surface of the almost semi-spherical lens HL and the upper surface of the recording medium RM is larger, the evanescent light E attenuates and it can not be effectively used for the recording or reproducing of the information. However, when it is set that the distance Δ between the almost semi-spherical lens HL and the upper surface of the recording medium RM is smaller, (for example, lower than the wavelength of the transmitted light), because, before the evanescent light E attenuates, the light reaches the recording medium RM, the light can be used for the recording or reproducing of the information. That is, when the recording or reproducing of the information is conducted by using the luminous flux within the range which exceeds the

first predetermined angle θ1 and which is to the second predetermined angle θ2, and which is totally reflected, the light converging optical system whose image side numerical aperture (NA) is not smaller than 1.0 can be structured. In this connection, the light converging optical system is not only the above final optical element, but may also be structured of a plurality of optical elements. Further, when the distance Δ is smaller than the wavelength of the information recording light used for the recording or reproducing of the information, it can be effectively used before the attenuation of the evanescent light.

~~In an optical pick-up apparatus described in (2)~~ In a second structure of the optical pick-up apparatus of the invention, ~~because~~ the light conversing optical system has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is in contact with the surface of the optical information recording medium. Thus, the luminous flux to a predetermined angle θ2 is not totally reflected on the lower surface of the almost semi-spherical lens HL and transmits it, and the recording or reproducing of the information can be conducted.

~~In an optical pick up apparatus described in (3)~~ In a third structure of the optical pick-up apparatus of the invention, the light converging optical system has the final optical element opposite to the light information recording medium, and ~~because~~ the final optical surface of the final optical element approximates to the surface of the optical information recording medium by spacing the distance not larger than one fourth of the wavelength of the light source. Thus, the recording or reproducing of the information can be conducted by using the evanescent light E.

~~In an optical pick up apparatus described in (4)~~ In a fourth structure of the optical pick-up apparatus of the invention, ~~because~~ a plurality of light converging optical systems are provided, and each of light converging optical systems is used for recording or reproducing of the information for respectively different information recording layers. Thus, when the recording or reproducing of the information is conducted onto each of information recording layers of the multi-layer type optical information recording medium, the aberration correction corresponding to each layer can be independently conducted, and when the recording or reproducing of the information is conducted onto the different information recording layers, an appropriate and

quick recording or reproducing of the information can be conducted.

~~In an optical pick-up apparatus described in (5)~~ In a fifth structure of the optical pick-up apparatus of the invention, the apparatus has a selection means to select the information recording layer to be recorded or reproduced from a laminated plurality of information recording layers, and ~~because~~ the recording or reproducing of the information is conducted on the information recording layer selected by the selection means. Thus, the recording or reproducing of the information can be appropriately conducted on each of information recording layers of the multi-layer type optical information recording medium.

~~In an optical pick-up apparatus described in (6)~~ In a sixth structure of the optical pick-up apparatus of the invention, the light converging optical system has at least 2 final optical elements, and each of final optical elements is used for the recording or reproducing of the information onto the respective different information recording layers, and when the selection means selects any one of the plurality of final optical elements~~, because~~. Because the recording or reproducing of the information is conducted on the information recording layer corresponding to the selected

final optical element, the aberration correction corresponding to each layer can be independently conducted, and the recording or reproducing of the information can be appropriately conducted on each of information recording layers of the multi-layer type optical information recording medium.

~~In an optical pick up apparatus described in (7)~~ In a seventh structure of the optical pick-up apparatus of the invention, ~~because~~ the selection means changes the wavelength of the light source corresponding to each of the laminated information recording layers for the information to be recorded or reproduced. Thus, the light converging optical system to irradiate the light onto each of the information recording layers or the detection optical system of the light reflected from that can be commonly used, and although the apparatus is a structure which is simple, and whose space saving can be intended, the appropriate and quick recording or reproducing of the information can be conducted.

~~In an optical pick up apparatus described in (8)~~ In an eighth structure of the optical pick-up apparatus of the invention, ~~because~~ the selection means is provided with at least one optical element to change the divergence degree or convergence degree of the incident light into the final

optical element corresponding to each of laminated information recording layers to record or reproduce the information on the light source side of the final optical element. Thus, when the recording or reproducing of the information is conducted on each of information recording layers, the degree of freedom in the optical design work such as the aberration correction can be expanded. As an example of the optical element to change the divergence degree or convergence degree of the incident light into the final optical element, it includes a beam expander, coupling lens, or refractive index changing liquid crystal plate, but it is not limited to these elements.

~~In an optical pick up apparatus described in (9)~~ In a ninth structure of the optical pick-up apparatus of the invention, the optical element to change the divergence degree or convergence degree of the incident light into the final optical element has a positive lens group having the positive refractive power and a negative lens group having the negative refractive power, and at least one lens group is displaceable movable element, and the aberration correction can be arbitrarily conducted when the recording or reproducing of the information is conducted onto each of information recording layers.

~~In an optical pick-up apparatus described in (10)~~ In a tenth structure of the optical pick-up apparatus of the invention, the optical element to change the divergence degree or convergence degree of the incident light into the final optical element is formed of one positive lens, and one negative lens, and because at least one of them is a displaceable and movable element, the aberration correction can be arbitrarily conducted when the recording or reproducing of the information is conducted onto each of information recording layers.

~~In an optical pick-up apparatus described in (11)~~ In an eleventh structure of the optical pick-up apparatus of the invention, the information recording medium includes the first recording layer and second recording layer in the order of nearer distance from the final optical element, and in a case where the recording or reproducing is conducted onto the first recording layer~~, because~~. Because the interval between the negative lens group and the positive lens group is increased more than a case where the recording or reproducing of the information is conducted onto the second recording layer, it can cope with a fact that it is necessary that the divergent angle of the incident light into the second

recording layer is increased more than the incident light into the first recording layer.

~~In an optical pick up apparatus described in (12)~~ In a twelfth structure of the optical pick-up apparatus of the invention, the optical element to change the divergence degree or convergence degree of the incident light into the final optical element corrects the spherical aberration or the axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer to record or reproduce. Because the optical element to change the divergence degree or convergence degree of the incident light into the final optical element not only change the information recording layer to record or reproduce the information, but also charges the change of the spherical aberration generated in the final optical element on the optical recording surface of the objective layer, and correction of the axial chromatic aberration, it is not necessary that another optical element to correct these aberrations is used, and the compactness of the optical system and the cost reduction thereof can be intended.

~~In an optical pick up apparatus described in (13)~~ In a thirteenth structure of the optical pick-up apparatus of the invention, the optical element to correct the variation of

the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

Where νdP : the average of Abbe's number of d-line of total positive lens including the positive lens (group),

νdN : the average of Abbe's number of d-line of total negative lens including the negative lens (group).

The above expression (1) shows the condition relating to the correction of axial chromatic aberration. Due to the minute variation of the oscillation wavelength of the light source or the temperature and humidity change, in the case where the spherical aberration of the final optical element changes, when a means to correct this is composed of, for example, the optical element which is displaceable in the optical axis direction, such the optical element is moved by an adequate amount, and the divergence degree of the luminous flux incident to the final optical element can be changed so that the spherical aberration of the final optical element becomes minimum. However, when the materials of the positive lens and negative lens in the means to correct the variation of the spherical aberration are selected so as to satisfy the expression (1), the chromatic aberration having the reversal

polarity to the chromatic aberration generated in the final optical element can be generated. Accordingly, the axial chromatic aberrations are cancelled with each other, and the wave front which transmits the means to correct the variation of the spherical aberration and the final optical element, and is focused onto the optical information recording medium, is in a condition that the axial chromatic aberration is suppressed small.

~~In an optical pick-up apparatus described in (14)~~ In a fourteenth structure of the optical pick-up apparatus of the invention, the νdP and the νdN satisfy the following expressions.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

When the difference between Abbe's numbers of the positive lens and the negative lens is increased, because the chromatic aberration of the reversal polarity to the final optical element can be generated larger, the axial chromatic aberration of the optical information recording and reproducing optical system can be corrected better.

~~In an optical pick-up apparatus described in (15)~~ In a fifteenth structure of the optical pick-up apparatus of the

invention, ~~because~~ the optical element to vary the divergence degree or convergence degree of the incident light to the final optical element can change the refractive index distribution. Thus, the recording or reproducing of the information can be conducted more adequately onto each of information recording layers. Herein, as the element which can change the refractive index, the refractive index change liquid crystal plate is so referred, but it is not limited to this.

~~In an optical pick-up apparatus described in (16)~~ In a sixteenth structure of the optical pick-up apparatus of the invention, ~~because~~ at least one optical element which structures the light converging optical system, has at least one aspherical optical surface, by using such the aspherical optical surface. Thus, the spherical aberration generated in the optical system can be corrected.

~~In an optical pick-up apparatus described in (17)~~ In a seventeenth structure of the optical pick-up apparatus of the invention, at least one optical element which structures the light converging optical system, is provided with the diffraction surface having the ring band-like diffraction structure~~, and because,~~. Because, by using such the diffraction surface, the axial chromatic aberration can be

effectively corrected, it is not necessary that the optical element for the axial chromatic aberration correction is newly provided, and the low cost and space saving is possible. In this connection, for the optical element having the diffraction surface, in the case where the optical system is structured by a plurality of lenses, one lens is included, and particularly, when the optical system is structured by the positive lens or negative lens, it includes one of them. Further, it also includes the optical element which is separately provided other than these lenses.

~~In an optical pick-up apparatus described in (18)~~ In an eighteenth structure of the optical pick-up apparatus of the invention, ~~because~~ at least one optical system constituting the light converging optical system is formed of a material whose specific gravity is not larger than 2.0~~, thereby,~~. Thus, the weight reduction can be intended, and the burden onto the displacing apparatus such as the focusing apparatus can be lightened.

~~In an optical pick-up apparatus described in (19)~~ In a nineteenth structure of the optical pick-up apparatus of the invention, ~~because~~ at least one optical element constituting the light converging optical system is formed of a plastic material. Thus, the weight reduction can be attained, and

while lightening the burden onto the displacing apparatus such as the focusing apparatus, the processing such as the formation of the diffraction structure or aspheric surface can be easily conducted.

~~In an optical pick-up apparatus described in (20)~~ In a twentieth structure of the optical pick-up apparatus of the invention, ~~because~~ at least one optical element constituting the light converging optical system is formed of a material whose saturation water absorption is not larger than 0.5 %. Thus, the deterioration of the performance at the time of humidity change can be suppressed.

~~In an optical pick-up apparatus described in (21)~~ In a twenty first structure of the optical pick-up apparatus of the invention, ~~because~~ at least one optical element constituting the light converging optical system is formed of a material whose internal transmissivity is not smaller than 85 % at the thickness of 3 mm to the light of the oscillation wavelength of the light source. Thus, the using efficiency of the incident light can be in creased.

~~In an optical pick-up apparatus described in (22)~~ In a twenty second structure of the optical pick-up apparatus of the invention, ~~because~~ the light converging optical system has at least 2 apertures to regulate the image side numerical

aperture in a plurality of information recording layers of the optical information recording medium. Thus, it can change the aperture sop to regulate the information recording light for each of information layers to be recorded or reproduced, and the image formation at a predetermined image side numerical aperture (NA) can be conducted in each of information recording layers.

~~In an optical pick-up apparatus described in (23)~~ In a twenty third structure of the optical pick-up apparatus of the invention, at least one of the apertures is placed between the final optical element and the information recording medium. For example, when the final optical element is a catadioptric, the final surface can be divided into the mirror surface portion and the transmission portion to transmit the converging light. In such the case, when the transmission portion is made a minute opening and simultaneously the role of the aperture is made to be performed, the using efficiency of the incident light can be increased, and the low cost, size reduction, and weight reduction can be intended.

~~In an optical pick up apparatus described in (24)~~ In a twenty fourth structure of the optical pick-up apparatus of the invention, ~~because~~ at least one optical element of the

optical system is formed by etching. Thus, the minute optical element can be accurately molded.

~~An optical pick-up apparatus described in (25)~~ A twenty fifth structure of the optical pick-up apparatus of the invention has the light source, and the light converging optical system to light converge the luminous flux emitted from the light source onto any one information recording layer of the optical information recording medium having a laminated plurality of information recording layers, and in the optical pick-up apparatus by which the recording and/or reproducing of the information is conducted onto the optical information recording medium, the light converging optical system has the final optical element opposite to the optical information recording medium, spacing a smaller interval than the wavelength of the light source, and when the light converging optical system light converges the luminous flux whose image side numerical aperture is not smaller than 1.0, because the recording or reproducing of the information is conducted onto the information recording layer, the high density optical information recording or reproducing can be conducted onto the optical information recording medium, in the same manner as in the first structure of the optical pick-up apparatus ~~described in (1)~~. Further, because the air

layer can be provided between the optical information recording medium and the final optical element, the optical information recording medium can be made, for example, to a circular rotating disk such as a CD, and the recording and/or reproducing of the information can be conducted at the higher speed, and the optical information recording medium can be made to a removable one with excellent handling.

~~An optical pick-up apparatus described in (26)~~ A twenty sixth structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical system has the final optical element opposed to the optical information recording medium, and the final optical surface of the final optical element is approximate to the surface of the optical information recording medium spacing the distance not larger than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~An optical pick-up apparatus described in (27)~~ A twenty seventh structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical systems are provided plural numbers, and each of the light converging optical systems is used for recording or

reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~An optical pick-up apparatus described in (28)~~ A twenty eighth structure of the optical pick-up apparatus of the invention is characterized in that it has the selection means to select the information recording layers to be recorded or reproduced, and the information is recorded or reproduced onto the information recording layers selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~An optical pick-up apparatus described in (29)~~ A twenty ninth structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical system has at least 2 final optical elements, and each final optical element is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer

corresponding to the selected final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~An optical pick-up apparatus described in (30)~~ A thirtieth structure of the optical pick-up apparatus of the invention is characterized in that the selection means changes the wavelength of the light source corresponding to each of laminated information recording layers for the information to be recorded or reproduced. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~An optical pick-up apparatus described in (31)~~ A thirty first structure of the optical pick-up apparatus of the invention is characterized in that the selection means provides at least one optical element by which the divergence degree or convergence degree of the incident light into the final optical element is varied corresponding to each of laminated information recording layers for the information to be recorded or reproduced, on the light source side of the final optical element. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~An optical pick-up apparatus described in (32)~~ A thirty second structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical pick-up apparatus described in (33)~~ A thirty third structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element is composed of a positive lens and a negative lens, and at least one lens of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical pick-up apparatus described in (34)~~ A thirty fourth structure of the optical pick-up apparatus of the invention is characterized in that the information recording

medium includes the first recording layer and the second recording layer in the order of the distance nearer to the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the distance between the negative lens group and the positive lens group or the distance between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical pick-up apparatus described in (35)~~ A thirty fifth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergent degree or the convergent degree of the incident light into the final optical element corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer to be recorded or reproduced. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical pick-up apparatus described in (36)~~ A thirty sixth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfy the following expression.

$$vdP > vdN \qquad (1)$$

Where, vdP : the average of Abbe's number of d line of the all positive lenses including the positive lens (group), and vdN : the average of Abbe's number of d line of the all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical pick-up apparatus described in (37)~~ A thirty seventh structure of the optical pick-up apparatus of the invention is characterized in that the vdP and the vdN satisfy the following expression.

$$vdP > 55 \qquad (2)$$

$$vdN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical pick-up apparatus described in (38)~~ A thirty eighth of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergent degree or convergent degree of the incident light into the final optical element can change the refractive index. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical pick-up apparatus described in (39)~~ A thirty ninth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical pick-up apparatus described in (40)~~ A fortieth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system has the diffraction surface having the ring band-like diffraction structure. The effect of such the invention is the same as

in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical pick-up apparatus described in (41)~~ A forty first structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical pick-up apparatus described in (42)~~ A forty second structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical pick-up apparatus described in (43)~~ A forty third structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is

the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical pick up apparatus described in (44)~~ A forty fourth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transimissivity is not smaller than 85 % in the thickness of 3 mm to the light of the oscillation wavelength of the light source. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical pick up apparatus described in (45)~~ A forty fifth structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical system has at least 2 apertures to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical pick up apparatus described in (46)~~ A forty sixth structure of the optical pick-up apparatus of the

invention is characterized in that at least one of the apertures is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical pick-up apparatus described in (47)~~ A forty seventh structure of the optical pick-up apparatus of the invention is characterized in that at least one of optical element of the light converging optical system is formed by the etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In an optical pick-up apparatus described in (48)~~ In a forty eighth structure of the optical pick-up apparatus of the invention which has a light source, and a light converging optical system to converge the light onto any one information recording layer of the optical information recording medium having a laminated plurality of information recording layers, and in which the recording and/or reproducing of the information is conducted onto the optical information recording medium, the optical pick-up apparatus is characterized in that the optical information recording

medium has a transparent substrate whose thickness is larger than the wavelength of the light source, and the light converging optical system has a final optical element opposite to the optical information recording medium spacing the distance smaller than the wavelength of the light source, and when the light converging optical system converges the luminous flux whose image side numerical aperture is larger than 1.0 onto the information recording layer through the transparent substrate, the recording or reproducing of the information is conducted onto the information recording layer.

One problem in the case where the near field effect is used, is that it is necessary that the distance between the final optical element and the optical information recording medium is set smaller than the wavelength of the using wavelength. However, in the case of the removable recording medium, considering the influence of flaw when the user handles it, or dust, it is common that the protective layer is provided on the information recording surface. The thickness of the protective layer is, in many cases, more than the wavelength of the light source used.

Therefore, in the present invention, using the near field effect of wide sense, it is considered that the

recording or reproducing is conducted. When more specifically described, as described above, the evanescent light has the characteristic that it exponential functionally attenuates as it is separated from the final optical element, and when the transparent substrate (TP in Fig. 1) is placed in its light path, the evanescent light incident to that place, becomes again the propagation light, and has the characteristic that it propagates in the transparent substrate as the normal light. It is called the near field effect in the wide sense. In the present invention, using such the characteristic, when the evanescent light emitted from the final optical element is received by the transparent substrate and made to a propagation light, the recording or reproducing of the information can be conducted also onto the information recording layer which is remote from the final optical surface of the final optical element more than the wavelength of the light source. In this connection, in the optical information recording medium, in many cases, the transparent protective layer covering the information recording surface is provided, and such the protective layer can perform the function as the transparent substrate of the present invention. Accordingly, the interval Δ between the final optical element and the surface of the protective layer

of the optical information recording medium may be smaller than the wavelength of the in formation recording light. Herein, when the layer can transmit the light, the transparent substrate may not be colored or plate-like one.

~~An optical pick-up apparatus described in (49)~~ A forty ninth structure of the optical pick-up apparatus of the invention is characterized in that the final optical surface of the final optical element is approximate to the surface of the optical information recording medium spacing with the distance smaller than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~An optical pick-up apparatus described in (50)~~ A fiftieth structure of the optical pick-up apparatus of the invention is characterized in that a plurality of light converging optical systems are provided, and each of light converging optical systems is used for the recording or reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~An optical pick-up apparatus described in (51)~~ A fifty first structure of the optical pick-up apparatus of the invention is characterized in that the apparatus has a selection means for selecting the information recording layer to be recorded or reproduced from the laminated plurality of plurality of information recording layers, and the recording or reproducing of the information is conducted onto the information recording layer selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~An optical pick-up apparatus described in (52)~~ A fifty second structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical system has at least 2 final optical elements, and each of final optical elements is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer corresponding to the selected final optical element. The effect of such the

invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~An optical pick up apparatus described in (53)~~ A fifty third structure of the optical pick-up apparatus of the invention is characterized in that the selection means changes the wavelength of the light source corresponding to each of laminated information recording layers for the information to be recorded and reproduced. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~An optical pick up apparatus described in (54)~~ A fifty fourth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, corresponding to each of laminated information recording layers for the information to be recorded and reproduced, is provided on the light source side of the final optical element. The effect of such the invention is the same as in the eighth structure of the optical pickup apparatus ~~the invention described in (8)~~.

~~An optical pick up apparatus described in (55)~~ A fifty fifth structure of the optical pick-up apparatus of the

invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical pick-up apparatus described in (56)~~ A fifty sixth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element is composed of one positive lens and one negative lens, and at least one of them is [[is]] a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical pick-up apparatus described in (57)~~ A fifty seventh structure of the optical pick-up apparatus of the invention is characterized in that the information recording medium includes the first recording layer and the second

recording layer in the order of the distance nearer to the final optical element, and when the recording or reproducing of the information is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the distance between the positive lens and the negative lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical pick-up apparatus described in (58)~~ A fifty eighth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element corrects the spherical aberration or the axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer to be recorded or reproduced. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical pick-up apparatus described in (59)~~ A fifty ninth structure of the optical pick-up apparatus of the

invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

where, νdP : the average of Abbe's number of d line of all positive lens including the positive lens (group), νdN : the average of Abbe's number of d line of all negative lens including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical pick-up apparatus described in (60)~~ A sixtieth structure of the optical pick-up apparatus of the invention is characterized in that the value νdP and the value νdN satisfy the following expressions.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical pick-up apparatus described in (61)~~ A sixty first structure of the optical pick-up apparatus of the

invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element can changes the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical pick-up apparatus described in (62)~~ A sixty second structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical pick-up apparatus described in (63)~~ A sixty third structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system has a diffraction surface having the ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical pick-up apparatus described in (64)~~ A sixty fourth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical pick-up apparatus described in (65)~~ A sixty fifth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of a plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical pick-up apparatus described in (66)~~ A sixty sixth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of a material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical pick-up apparatus described in (67)~~ A sixty seventh structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of a material whose internal transmissivity at the thickness of 3 mm to the light of oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical pick-up apparatus described in (68)~~ A sixty eighth structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical pick-up apparatus described in (69)~~ A sixty ninth structure of the optical pick-up apparatus of the invention is characterized in that at least one of the diaphragms is positioned between the final optical element

and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical pick-up apparatus described in (70)~~ A seventieth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In an optical pick-up apparatus described in (71)~~ In a seventy first structure of the optical pick-up apparatus of the invention which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a laminated plurality of information recording layers, and by which the recording and/or reproducing of the information is conducted onto the optical information recording medium, because the optical element changes the information recording layer for the information to be recorded or reproduced is provided between the light source

and the final optical element of the light converging optical system, the information recording light can be adequately irradiated onto each of information recording layers of the multi-layer type optical information recording medium by the simple and low cost structure.

~~An optical pick-up apparatus described in (72)~~ A seventy second structure of the optical pick-up apparatus of the invention is characterized in that the optical element to change the information recording layers onto which the information is to be recorded or reproduced changes the divergence degree or convergence degree of the incident light into the final optical element. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~An optical pick-up apparatus described in (73)~~ A seventy third structure of the optical pick-up apparatus of the invention is characterized in that the optical element by which the divergence degree or convergence degree of the incident light into the final optical element is changed, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the

same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical pick-up apparatus described in (74)~~ A seventy fourth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergent degree or convergence degree of the incident light into the final optical element is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical pick-up apparatus described in (75)~~ A seventy fifth structure of the optical pick-up apparatus of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention

is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical pick-up apparatus described in (76)~~ A seventy sixth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical pick-up apparatus described in (77)~~ A seventy seventh structure of the optical pick-up apparatus of the invention is characterized in that the optical element which corrects the spherical aberration and axial chromatic aberration satisfies the following expression.

$$vdP > vdN \qquad (1)$$

Where, vdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), vdN: the average of Abbe's number of the d line of all

negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical pick-up apparatus described in (78)~~ A seventy eighth structure of the optical pick-up apparatus of the invention is characterized in that the vdP and the vdN satisfy the following expressions.

$$vdP > 55 \qquad (2)$$

$$vdN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical pick-up apparatus described in (79)~~ A seventy ninth structure of the optical pick-up apparatus of the invention is characterized in that the optical element to vary the divergence degree and the convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical pick-up apparatus described in (80)~~ A eightieth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical pick-up apparatus described in (81)~~ A eighty first structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system has the diffraction surface having the ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical pick-up apparatus described in (82)~~ A eighty second structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in

the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical pick up apparatus described in (83)~~ A eighty third structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical pick up apparatus described in (84)~~ A eighty fourth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical pick up apparatus described in (85)~~ A eighty fifth structure of the optical pick-up apparatus of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of oscillation wavelength of the

light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical pick-up apparatus described in (86)~~ A eighty sixth structure of the optical pick-up apparatus of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical pick-up apparatus described in (87)~~ A eighty seventh structure of the optical pick-up apparatus of the invention is characterized in that at least one diaphragm of the diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical pick-up apparatus described in (88)~~ A eighty eighth structure of the optical pick-up apparatus of the

invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In a light converging optical system of an optical pick-up apparatus described in (89)~~ In a eighty ninth structure of the light converging optical system of the optical pick-up apparatus of the invention which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a laminated plurality of information recording layers, and by which the recording and/or reproducing of the information is conducted onto the optical information recording medium, the light converging optical system is characterized in that, when the light converging optical system light converges the luminous flux whose image side numerical aperture is not smaller than 1.0, onto the information recording layer, the recording or reproducing of the information is conducted onto the information recording layer. The effect of such the

invention is the same as in the first structure of the optical pick-up apparatus ~~the invention described in (1)~~.

~~A light converging optical system of an optical pick-up apparatus described in (90)~~ A ninetieth structure of the light converging optical system of the invention is characterized in that it has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is in contact with the surface of the optical information recording medium. The effect of such the invention is the same as in the second structure of the optical pick-up apparatus ~~the invention described in (2)~~.

~~A light converging optical system of an optical pick-up apparatus described in (91)~~ A ninety first structure of the light converging optical system of the invention is characterized in that it has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is approximate to the surface of the optical information recording medium spacing the interval not larger than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~A light converging optical system of an optical pick-up apparatus described in (92)~~ A ninety second structure of the light converging optical system of the invention is characterized in that a plurality of light converging optical systems are provided, and each of light converging systems is used for the recording or reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~A light converging optical system of an optical pick-up apparatus described in (93)~~ A ninety third structure of the light converging optical system of the invention is characterized in that it has a selection means for selecting the information recording layer onto which the recording or reproducing is to be conducted, from a laminated plurality of information recording layers, and the recording or reproducing of the information is conducted onto the information recording layer selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~A light converging optical system of an optical pick up apparatus described in (94)~~ A ninety fourth structure of the light converging optical system of the invention is characterized in that the light converging optical system has at least 2 final optical elements, and each of the final optical elements is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer corresponding to the selected final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~A light converging optical system of an optical pick up apparatus described in (95)~~ A ninety fifth structure of the light converging optical system of the invention is characterized in that the selection means changes the wavelength of the light source corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as

in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~A light converging optical system of an optical pick up apparatus described in (96)~~ A ninety sixth structure of the light converging optical system of the invention is characterized in that the selection means provides at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element on the light source side of the final optical element, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~A light converging optical system of an optical pick up apparatus described in (97)~~ A ninety seventh structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The

effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~A light converging optical system of an optical pick up apparatus described in (98)~~ A ninety eighth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~A light converging optical system of an optical pick up apparatus described in (99)~~ A ninety ninth structure of the light converging optical system of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive

lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~A light converging optical system of an optical pick up apparatus described in (100)~~ A one hundredth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~A light converging optical system of an optical pick up apparatus described in (101)~~ A one hundred first structure of the light converging optical system of the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

Where, νdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), νdN: the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~A light converging optical system of an optical pick up apparatus described in (102)~~ A one hundred second structure of the light converging optical system of the invention is characterized in that the νdP and the νdN satisfy the following expressions.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~A light converging optical system of an optical pick up apparatus described in (103)~~ A one hundred third structure of the light converging optical system of the invention is characterized in that the optical element to vary the

divergence degree or convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~A light converging optical system of an optical pick up apparatus described in (104)~~ A one hundred fourth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~A light converging optical system of an optical pick up apparatus described in (105)~~ A one hundred fifth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~A light converging optical system of an optical pick up apparatus described in (106)~~ A one hundred sixth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~A light converging optical system of an optical pick up apparatus described in (107)~~ A one hundred seventh structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~A light converging optical system of an optical pick up apparatus described in (108)~~ A one hundred eighth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of

the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~A light converging optical system of an optical pick-up apparatus described in (109)~~ A one hundred ninth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~A light converging optical system of an optical pick-up apparatus described in (110)~~ A one hundred tenth structure of the light converging optical system of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure

of the optical pick-up apparatus ~~the invention described in (22)~~.

~~A light converging optical system of an optical pick up apparatus described in (111)~~ A one hundred eleventh structure of the light converging optical system of the invention is characterized in that at least one of diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~A light converging optical system of an optical pick up apparatus described in (112)~~ A one hundred twelfth structure of the light converging optical system of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In a light converging optical system of an optical pick up apparatus described in (113)~~ In a one hundred thirteenth structure of the light converging optical system of the optical pick-up apparatus of invention which has the light source and the light converging optical system to light

converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a laminated plurality of information recording layers, and by which the recording and/or reproducing of the information is conducted onto the optical information recording medium, the light converging optical system is characterized in that, it has the final optical element opposite to the optical information recording medium spacing the distance not larger than the wavelength of the light source, and when the light converging optical system light converges the luminous flux whose image side numerical aperture is not smaller than 1.0, onto the information recording layer, the recording or reproducing of the information is conducted onto the information recording layer. The effect of such the invention is the same as in the twenty fifth structure of the optical pick-up apparatus ~~the invention described in (25)~~.

~~A light converging optical system of an optical pick up apparatus described in (114)~~ A one hundred fourteenth structure of the light converging optical system of the invention is characterized in that it has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is

approximate to the surface of the optical information recording medium spacing the distance not larger than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~A light converging optical system of an optical pick-up apparatus described in (115)~~ A one hundred fifteenth structure of the light converging optical system of the invention is characterized in that a plurality of light converging elements are provided, and each of light converging elements is used for the recording or reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~A light converging optical system of an optical pick-up apparatus described in (116)~~ A one hundred sixteenth structure of the light converging optical system of the invention is characterized in that it has a selection means for selecting the information recording layer onto which the recording or reproducing is to be conducted, from the laminated plurality of information recording layers, and the recording or reproducing of the information is conducted onto

the information recording layer selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~A light converging optical system of an optical pick up apparatus described in (117)~~ A one hundred seventeenth structure of the light converging optical system of the invention is characterized in that it has at least 2 final optical element and each of the final optical elements is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer corresponding to the selected final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~A light converging optical system of an optical pick up apparatus described in (118)~~ A one hundred eighteenth structure of the light converging optical system of the invention is characterized in that the selection means changes the wavelength of the light source corresponding to

each of information recording layers onto which the recording and reproducing of the information is to be conducted. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~A light converging optical system of an optical pick up apparatus described in (119)~~ A one hundred nineteenth structure of the light converging optical system of the invention is characterized in that the selection means is provided with, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information to be conducted, at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element on the light source side of the final optical element. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~A light converging optical system of an optical pick up apparatus described in (120)~~ A one hundred twentieth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the

positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~A light converging optical system of an optical pick up apparatus described in (121)~~ A one hundred twenty first structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~A light converging optical system of an optical pick up apparatus described in (122)~~ A one hundred twenty second structure of the light converging optical system of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing

is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~A light converging optical system of an optical pick-up apparatus described in (123)~~ A one hundred twenty third structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~A light converging optical system of an optical pick-up apparatus described in (124)~~ A one hundred twenty fourth structure of the light converging optical system of the

invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

Where, νdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), νdN: the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~A light converging optical system of an optical pick-up apparatus described in (125)~~ A one hundred twenty fifth structure of the light converging optical system of the invention is characterized in that the νdP and the νdN satisfy the following expressions.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~A light converging optical system of an optical pick up apparatus described in (126)~~ A one hundred twenty sixth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~A light converging optical system of an optical pick up apparatus described in (127)~~ A one hundred twenty seventh structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~A light converging optical system of an optical pick up apparatus described in (128)~~ A one hundred twenty eighth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has

a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~A light converging optical system of an optical pick-up apparatus described in (129)~~ A one hundred twenty ninth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~A light converging optical system of an optical pick-up apparatus described in (130)~~ A one hundred thirtieth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~A light converging optical system of an optical pick-up apparatus described in (131)~~ A one hundred thirty first

structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~A light converging optical system of an optical pick up apparatus described in (132)~~ A one hundred thirty second structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~A light converging optical system of an optical pick up apparatus described in (133)~~ A one hundred thirty third structure of the light converging optical system of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the

image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~A light converging optical system of an optical pick up apparatus described in (134)~~ A one hundred thirty fourth structure of the light converging optical system of the invention is characterized in that at least one of diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~A light converging optical system of an optical pick up apparatus described in (135)~~ A one hundred thirty fifth structure of the light converging optical system of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In a light converging optical system of an optical pick up apparatus described in (136)~~ In a one hundred thirty

sixth structure of the light converging optical system of the optical pick-up apparatus which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a laminated plurality of information recording layers, and by which the recording and/or reproducing of the information is conducted onto the optical information recording medium, the light converging optical system is characterized in that the optical information recording medium has a transparent substrate whose thickness is not smaller than the wavelength of the light source on the information recording layer nearest to the light converging optical system side, and the light converging optical system has the final optical element opposite to the optical information recording medium spacing the distance not larger than the wavelength of the light source, and when the light converging optical system light converges the luminous flux whose image side numerical aperture is not smaller than 1.0, onto the information recording layer through the transparent substrate, the recording or reproducing of the information is conducted onto the information recording layer. The effect of such the invention is the same as in the forty eighth

structure of the optical pick-up apparatus ~~the invention described in (48)~~.

~~A light converging optical system of an optical pick up apparatus described in (137)~~ A one hundred thirty seventh structure of the light converging optical system of the invention is characterized in that the final optical surface of final optical element is approximate to the surface of the optical information recording medium spacing the interval not larger than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~A light converging optical system of an optical pick-up apparatus described in (138)~~ A one hundred thirty eighth structure of the light converging optical system of the invention is characterized in that a plurality of light converging optical systems are provided, and each of light converging optical systems is used for the recording or reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~A light converging optical system of an optical pick-up apparatus described in (139)~~ A one hundred thirty ninth structure of the light converging optical system of the invention is characterized in that it has a selection means for selecting the information recording layer onto which the recording or reproducing is to be conducted, from the laminated plurality of information recording layers, and the recording or reproducing of the information is conducted onto the information recording layer selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~A light converging optical system of an optical pick-up apparatus described in (140)~~ A one hundred fortieth structure of the light converging optical system of the invention is characterized in that a plurality of light converging optical systems are provided, and each of light converging optical systems is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer corresponding to the selected

final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~A light converging optical system of an optical pick-up apparatus described in (141)~~ A one hundred forty first structure of the light converging optical system of the invention is characterized in that the selection means changes the wavelength of the light source corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~A light converging optical system of an optical pick-up apparatus described in (142)~~ A one hundred forty second structure of the light converging optical system of the invention is characterized in that the selection means provides at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element on the light source side of the final optical element, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The

effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~A light converging optical system of an optical pick up apparatus described in (143)~~ A one hundred forty third structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~A light converging optical system of an optical pick up apparatus described in (144)~~ A one hundred forty fourth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such

the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~A light converging optical system of an optical pick-up apparatus described in (145)~~ A one hundred forty fifth structure of the light converging optical system of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~A light converging optical system of an optical pick-up apparatus described in (146)~~ A one hundred forty sixth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, corrects the

spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~A light converging optical system of an optical pick up apparatus described in (147)~~ A one hundred forty seventh structure of the light converging optical system of the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

Where, νdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), νdN: the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~A light converging optical system of an optical pick-up apparatus described in (148)~~ A one hundred forty eighth structure of the light converging optical system of the invention is characterized in that the νdP and the νdN satisfy the following expressions.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~A light converging optical system of an optical pick-up apparatus described in (149)~~ A one hundred forty ninth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~A light converging optical system of an optical pick-up apparatus described in (150)~~ A one hundred fiftieth structure of the light converging optical system of the invention is

characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~A light converging optical system of an optical pick-up apparatus described in (151)~~ A one hundred fifty first structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~A light converging optical system of an optical pick-up apparatus described in (152)~~ A one hundred fifty second structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~A light converging optical system of an optical pick up apparatus described in (153)~~ A one hundred fifty third structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~A light converging optical system of an optical pick up apparatus described in (154)~~ A one hundred fifty fourth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~A light converging optical system of an optical pick up apparatus described in (155)~~ A one hundred fifty fifth structure of the light converging optical system of the invention ~~A light converging optical system of an optical pick up apparatus described in (155)~~ is characterized in that at least one optical element constituting the light

converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~A light converging optical system of an optical pick-up apparatus described in (156)~~ A one hundred fifty sixth structure of the light converging optical system of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~A light converging optical system of an optical pick-up apparatus described in (157)~~ A one hundred fifty seventh structure of the light converging optical system of the invention is characterized in that at least one of diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the

optical pick-up apparatus ~~the invention described in (23)~~.

~~A light converging optical system of an optical pick up apparatus described in (158)~~ A one hundred fifty eighth structure of the light converging optical system of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In a light converging optical system of an optical pick up apparatus described in (159)~~ In a one hundred fifty ninth structure of the light converging optical system of the optical pick-up apparatus of the invention which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a laminated plurality of information recording layers, and by which the recording and/or reproducing of the information is conducted onto the optical information recording medium, the light converging optical system is characterized in that, it is provided with the optical element to change the information recording layer onto which the recording or reproducing of the information is

to be conducted, between the light source and the final optical element of the light converging optical system. The effect of such the invention is the same as in the seventy first structure of the optical pick-up apparatus ~~the invention described in (71)~~.

~~An optical pick-up apparatus described in (160)~~ A one hundred sixtieth structure of the light converging optical system of the invention is characterized in that the optical element to change the information recording layers onto which the information is to be recorded or reproduced varies the divergence degree or convergence degree of the incident light into the final optical element. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~An optical pick-up apparatus described in (161)~~ A one hundred sixty first structure of the light converging optical system of the invention is characterized in that the optical element by which the divergence degree or convergence degree of the incident light into the final optical element is changed, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such

the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical pick-up apparatus described in (162)~~ A one hundred sixty second structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergent degree or convergence degree of the incident light into the final optical element is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical pick-up apparatus described in (163)~~ A one hundred sixty third structure of the light converging optical system of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the

information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical pick-up apparatus described in (164)~~ A one hundred sixty fourth structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical pick-up apparatus described in (165)~~ A one hundred sixty fifth structure of the light converging optical system of the invention is characterized in that the optical element which corrects the spherical aberration and axial chromatic aberration satisfies the following expression.

$$vdP > vdN \qquad (1)$$

Where, vdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), vdN: the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical pick-up apparatus described in (166)~~ A one hundred sixty sixth structure of the light converging optical system of the invention is characterized in that the vdP and the vdN satisfy the following expressions.

$$vdP > 55 \qquad (2)$$

$$vdN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteen structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical pick-up apparatus described in (79)~~ A one hundred sixty seventh structure of the light converging optical system of the invention is characterized in that the optical element to vary the divergence degree and the convergence degree of the incident light into the final optical element can change the refractive index distribution.

The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical pick-up apparatus described in (168)~~ A one hundred sixty eighth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical pick-up apparatus described in (169)~~ A one hundred sixty ninth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system has the diffraction surface having the ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical pick-up apparatus described in (170)~~ A one hundred seventieth structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical

system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical pick-up apparatus described in (171)~~ A one hundred seventy first structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical pick-up apparatus described in (172)~~ A one hundred seventy second structure of the light converging optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical pick-up apparatus described in (173)~~ A one hundred seventy third structure of the light converging

optical system of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical pick up apparatus described in (174)~~ A one hundred seventy fourth structure of the light converging optical system of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical pick up apparatus described in (175)~~ A one hundred seventy fifth structure of the light converging optical system of the invention is characterized in that at least one diaphragm of the diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the

same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical pick-up apparatus described in (176)~~ A one hundred seventy sixth structure of the light converging optical system of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~An optical information recording and reproducing method described in (177)~~ A one hundred seventy seventh structure of the optical information recording and reproducing method of the invention is characterized in that, by using an optical pick-up apparatus which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium ~~having a laminated plurality of information recording layers~~, the recording or reproducing of the information is conducted onto the information recording layer by the luminous flux whose image side numerical aperture is not smaller than 1.0, from the light converging optical system. The effect of such

the invention is the same as in the first structure of the optical pick-up apparatus ~~the invention described in (1)~~.

~~An optical information recording and reproducing method described in (178)~~ A one hundred seventy eighth structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is in contact with the surface of the optical information recording medium. The effect of such the invention is the same as in the second structure of the optical pick-up apparatus ~~the invention described in (2)~~.

~~An optical information recording and reproducing method described in (179)~~ A one hundred seventy ninth structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is approximate to the surface of the optical information recording medium spacing the interval not larger than one fourth of the wavelength of the light source. The effect of such the invention is the

same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~An optical information recording and reproducing method described in (180)~~ A one hundred eightieth structure of the optical information recording and reproducing method of the invention is characterized in that a plurality of light converging optical systems are provided, and each of light converging optical systems is used for the recording or reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~An optical information recording and reproducing method described in (181)~~ A one hundred eighty first structure of the optical information recording and reproducing method of the invention is characterized in that the optical pick-up apparatus has a selection means for selecting the information recording layer onto which the recording or reproducing is to be conducted, from a laminated plurality of information recording layers, and the recording or reproducing of the information is conducted onto the information recording layer selected by the selection means. The effect of such the

invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~An optical information recording and reproducing method described in (182)~~ A one hundred eighty second structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 final optical elements, and each of the final optical elements is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects either one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer corresponding to the selected final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~An optical information recording and reproducing method described in (183)~~ A one hundred eighty third structure of the optical information recording and reproducing method of the invention is characterized in that the selection means changes the wavelength of the light source, corresponding to each of laminated information recording layers onto which the

recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~An optical information recording and reproducing method described in (184)~~ A one hundred eighty fourth structure of the optical information recording and reproducing method of the invention is characterized in that the selection means provides at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element on the light source side of the final optical element, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~An optical information recording and reproducing method described in (185)~~ A one hundred eighty fifth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the

positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical information recording and reproducing method described in (186)~~ A one hundred eighty sixth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical information recording and reproducing method described in (187)~~ A one hundred eighty seventh structure of the optical information recording and reproducing method of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or

reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical information recording and reproducing method described in (188)~~ A one hundred eighty eighth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical information recording and reproducing method described in (189)~~ A one hundred eighty ninth structure of the optical information recording and reproducing method of

the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$vdP > vdN \quad (1)$$

Where, vdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), vdN: the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical information recording and reproducing method described in (190)~~ A one hundred ninetieth structure of the optical information recording and reproducing method of the invention is characterized in that the vdP and the vdN satisfy the following expressions.

$$vdP > 55 \quad (2)$$

$$vdN < 35 \quad (3)$$

The effect of such the invention is the same as in the fourteen structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical information recording and reproducing method described in (191)~~ A one hundred ninety first structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical information recording and reproducing method described in (192)~~ A one hundred ninety second structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical information recording and reproducing method described in (193)~~ A one hundred ninety third structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has

a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical information recording and reproducing method described in (194)~~ A one hundred ninety fourth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical information recording and reproducing method described in (195)~~ A one hundred ninety fifth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical information recording and reproducing method described in (196)~~ A one hundred ninety sixth structure of

the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical information recording and reproducing method described in (197)~~ A one hundred ninety seventh structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical information recording and reproducing method described in (198)~~ A one hundred ninety eighth structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the

image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical information recording and reproducing method described in (199)~~ A one hundred ninety ninth structure of the optical information recording and reproducing method of the invention is characterized in that at least one of diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical information recording and reproducing method described in (200)~~ A two hundredth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In an optical information recording and reproducing method described in (201)~~ In a two hundred first structure of the optical information recording and reproducing method of invention, the optical pick-up apparatus has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a laminated plurality of information recording layers, and the optical information recording and reproducing method is characterized in that, when the light converging optical system light converges the luminous flux whose image side numerical aperture is not smaller than 1.0, onto the information recording layer, by using the optical pick-up apparatus having the final optical element opposite to the optical information recording medium, spacing the interval not larger than the wavelength of the light source, the recording or reproducing of the information is to conducted onto the information recording layer. The effect of such ~~the~~ invention is the same as in the twenty fifth structure of the optical pick-up apparatus ~~the invention described in (25)~~.

~~An optical information recording and reproducing method described in (202)~~ A two hundred second structure of the

optical information recording and reproducing method of the invention is characterized in that the light converging optical system has the final optical element opposite to the optical information recording medium, and the final optical surface of the final optical element is approximate to the surface of the optical information recording medium spacing the interval not larger than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~An optical information recording and reproducing method described in (203)~~ A two hundred third structure of the optical information recording and reproducing method of the invention ~~An optical information recording and reproducing method described in (203)~~ is characterized in that a plurality of light converging optical systems are provided, and each of light converging optical systems is used for the recording or reproducing of the information onto the ~~respectively different information recording layers~~. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~An optical information recording and reproducing method described in (204)~~ A two hundred fourth structure of the optical information recording and reproducing method of the invention is characterized in that the optical pick-up apparatus has a selection means for selecting the information recording layer onto which the recording or reproducing is to be conducted, from a laminated plurality of information recording layers, and the recording or reproducing of the information is conducted onto the information recording layer selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~An optical information recording and reproducing method described in (205)~~ A two hundred fifth structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 final optical elements, and each of the final optical elements is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer

corresponding to the selected final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~An optical information recording and reproducing method described in (206)~~ A two hundred sixth structure of the optical information recording and reproducing method of the invention is characterized in that the selection means changes the wavelength of the light source, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~An optical information recording and reproducing method described in (207)~~ A two hundred seventh structure of the optical information recording and reproducing method of the invention is characterized in that the selection means provides at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element on the light source side of the final optical element, corresponding to each of laminated information recording layers onto which the recording or

reproducing of the information is to be conducted. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~An optical information recording and reproducing method described in (208)~~ A two hundred eighth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical information recording and reproducing method described in (209)~~ A two hundred ninth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of one positive lens and one negative lens, and at least one of

them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical information recording and reproducing method described in (210)~~ A two hundred tenth structure of the optical information recording and reproducing method of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical information recording and reproducing method described in (211)~~ A two hundred eleventh structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the

incident light into the final optical element, corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical information recording and reproducing method described in (212)~~ A two hundred twelfth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$vdP > vdN \qquad (1)$$

Where, vdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), vdN : the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical information recording and reproducing method described in (212)~~ A two hundred thirteenth structure of the optical information recording and reproducing method of the invention is characterized in that the νdP and the νdN satisfy the following expressions.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical information recording and reproducing method described in (214)~~ A two hundred fourteenth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical information recording and reproducing method described in (215)~~ A two hundred fifteenth structure of the optical information recording and reproducing method of the

invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical information recording and reproducing method described in (216)~~ A two hundred sixteenth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical information recording and reproducing method described in (217)~~ A two hundred seventeenth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in

the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical information recording and reproducing method described in (218)~~ A two hundred eighteenth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical information recording and reproducing method described in (219)~~ A two hundred nineteenth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical information recording and reproducing method described in (220)~~ A two hundred twentieth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical

element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical information recording and reproducing method described in (221)~~ A two hundred twenty first structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical information recording and reproducing method described in (222)~~ A two hundred twenty second structure of the optical information recording and reproducing method of the invention is characterized in that at least one diaphragm of the diaphragms is positioned between the final optical element and the optical information recording medium. The

effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical information recording and reproducing method described in (223)~~ A two hundred twenty third structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~An optical information recording and reproducing method described in (224)~~ A two hundred twenty fourth structure of the optical information recording and reproducing method of the invention is characterized in that the optical pick-up apparatus which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a transparent substrate whose thickness is not smaller than the wavelength of the light source on the outermost information recording layer, and when, by using the optical pick-up apparatus having the final optical element opposite to the

transparent substrate spacing the interval not larger than the wavelength of the light source, the light converging optical system light-converges the luminous flux whose image side numerical aperture is not smaller than 1.0 onto the information recording layer, the recording or reproducing of the information is conducted onto the information recording layer. The effect of such the invention is the same as in the forty eighth structure of the optical pick-up apparatus ~~the invention described in (48)~~.

~~An optical information recording and reproducing method described in (225)~~ A two hundred twenty fifth structure of the optical information recording and reproducing method of the invention is characterized in that the final optical surface of the final optical element is approximate to the surface of the optical information recording medium spacing the interval not larger than one fourth of the wavelength of the light source. The effect of such the invention is the same as in the third structure of the optical pick-up apparatus ~~the invention described in (3)~~.

~~An optical information recording and reproducing method described in (226)~~ A two hundred twenty sixth structure of the optical information recording and reproducing method of the invention is characterized in that a plurality of light

converging optical systems are provided, and each of light converging optical systems is used for the recording or reproducing of the information onto the respectively different information recording layers. The effect of such the invention is the same as in the fourth structure of the optical pick-up apparatus ~~the invention described in (4)~~.

~~An optical information recording and reproducing method described in (227)~~ A two hundred twenty seventh structure of the optical information recording and reproducing method of the invention is characterized in that the optical pick-up apparatus has a selection means for selecting the information recording layer onto which the recording or reproducing is to be conducted, from a laminated plurality of information recording layers, and the recording or reproducing of the information is conducted onto the information recording layer selected by the selection means. The effect of such the invention is the same as in the fifth structure of the optical pick-up apparatus ~~the invention described in (5)~~.

~~An optical information recording and reproducing method described in (228)~~ A two hundred twenty eighth structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 final optical elements, and

each of the final optical elements is used for the recording or reproducing of the information onto the respectively different information recording layers, and when the selection means selects any one of the plurality of final optical elements, the recording or reproducing of the information is conducted onto the information recording layer corresponding to the selected final optical element. The effect of such the invention is the same as in the sixth structure of the optical pick-up apparatus ~~the invention described in (6)~~.

~~An optical information recording and reproducing method described in (229)~~ A two hundred twenty ninth structure of the optical information recording and reproducing method of the invention is characterized in that the selection means changes the wavelength of the light source, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the seventh structure of the optical pick-up apparatus ~~the invention described in (7)~~.

~~An optical information recording and reproducing method described in (230)~~ A two hundred thirtieth structure of the optical information recording and reproducing method of the

invention is characterized in that the selection means provides at least one optical element to vary the divergence degree or convergence degree of the incident light into the final optical element on the light source side of the final optical element, corresponding to each of laminated information recording layers onto which the recording or reproducing of the information is to be conducted. The effect of such the invention is the same as in the eighth structure of the optical pick-up apparatus ~~the invention described in (8)~~.

~~An optical information recording and reproducing method described in (231)~~ A two hundred thirty first structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical information recording and reproducing method described in (232)~~ A two hundred thirty second structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical information recording and reproducing method described in (233)~~ A two hundred thirty third structure of the optical information recording and reproducing method of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention

is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical information recording and reproducing method described in (234)~~ A two hundred thirty fourth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical information recording and reproducing method described in (235)~~ A two hundred thirty fifth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

Where, vdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), vdN : the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical information recording and reproducing method described in (236)~~ A two hundred thirty sixth structure of the optical information recording and reproducing method of the invention is characterized in that the vdP and the vdN satisfy the following expressions.

$$vdP > 55 \qquad (2)$$

$$vdN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical information recording and reproducing method described in (237)~~ A two hundred thirty seventh structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the

incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical information recording and reproducing method described in (238)~~ A two hundred thirty eighth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical information recording and reproducing method described in (239)~~ A two hundred thirty ninth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the seventeenth structure of the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical information recording and reproducing method described in (240)~~ A two hundred fortieth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical information recording and reproducing method described in (241)~~ A two hundred forty first structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical information recording and reproducing method described in (242)~~ A two hundred forty second structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is

not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical information recording and reproducing method described in (243)~~ A two hundred forty first structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical information recording and reproducing method described in (244)~~ A two hundred forty fourth structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty

second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical information recording and reproducing method described in (245)~~ A two hundred forty first structure of the optical information recording and reproducing method of the invention is characterized in that at least one diaphragm of the diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical information recording and reproducing method described in (246)~~ A two hundred forty first structure of the optical information recording and reproducing method of the invention ~~An optical information recording and reproducing method described in (246)~~ is characterized in that at least one optical element of the light converging optical system is ~~formed by etching. The effect of such the invention is the same as~~ in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

~~In an optical information recording and reproducing method described in (247)~~ In a two hundred forty seventh structure of the optical information recording and

reproducing method of the invention, in which, by using the optical pick-up apparatus which has the light source and the light converging optical system to light converge the luminous flux emitted from the light source onto any one of information recording layers of the optical information recording medium having a plurality of laminated information recording layers, the recording or reproducing of the information is conducted onto the optical information recording medium, the optical information recording and reproducing method is characterized in that, by a predetermined optical pick-up element provided between the light source and the final optical element of the light converging optical system, the information recording layer onto which the recording or reproducing of the information is to be conducted is changed. The effect of such the invention is the same as in the seventy first of the optical pick-up apparatus ~~the invention described in (71)~~.

~~An optical information recording and reproducing method described in (248)~~ A two hundred forty eighth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to change the information recording layer onto which the recording or reproducing of the information is to be

conducted, varies the divergence degree or convergence degree of the incident light into the final optical element. The effect of such the invention is the same as in the eighth structure of the optical pick-up appartus ~~the invention described in (8)~~.

~~An optical information recording and reproducing method described in (249)~~ A two hundred forty ninth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, has the positive lens group having the positive refractive power and the negative lens group having the negative refractive power, and at least one lens group of them is a displaceable movable element. The effect of such the invention is the same as in the ninth structure of the optical pick-up apparatus ~~the invention described in (9)~~.

~~An optical information recording and reproducing method described in (250)~~ A two hundred fiftieth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element, is composed of

one positive lens and one negative lens, and at least one of them is a displaceable movable element. The effect of such the invention is the same as in the tenth structure of the optical pick-up apparatus ~~the invention described in (10)~~.

~~An optical information recording and reproducing method described in (251)~~ A two hundred fifty first structure of the optical information recording and reproducing method of the invention is characterized in that the information recording medium includes the first recording layer and the second recording layer in the order of the distance nearer from the final optical element, and when the recording or reproducing is conducted onto the first recording layer, the interval between the negative lens group and the positive lens group or the interval between the negative lens and the positive lens is more increased than the case where the recording or reproducing of the information is conducted onto the second recording layer. The effect of such the invention is the same as in the eleventh structure of the optical pick-up apparatus ~~the invention described in (11)~~.

~~An optical information recording and reproducing method described in (252)~~ A two hundred fifty second structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to

vary the divergence degree or convergence degree of the incident light into the final optical element, corrects the spherical aberration or axial chromatic aberration which hinders the recording or reproducing of the information, in the information recording layer onto which the recording or reproducing is to be conducted. The effect of such the invention is the same as in the twelfth structure of the optical pick-up apparatus ~~the invention described in (12)~~.

~~An optical information recording and reproducing method described in (253)~~ A two hundred fifty third structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to correct the variation of the spherical aberration and the axial chromatic aberration satisfies the following expression.

$$\nu dP > \nu dN \qquad (1)$$

Where, νdP : the average of Abbe's number of the d line of all positive lenses including the positive lens (group), νdN : the average of Abbe's number of the d line of all negative lenses including the negative lens (group). The effect of such the invention is the same as in the thirteenth structure

of the optical pick-up apparatus ~~the invention described in (13)~~.

~~An optical information recording and reproducing method described in (254)~~ A two hundred fifty fourth structure of the optical information recording and reproducing method of the invention is characterized in that the value vdP and the value vdN satisfy the following expressions.

$$vdP > 55 \qquad (2)$$

$$vdN < 35 \qquad (3)$$

The effect of such the invention is the same as in the fourteenth structure of the optical pick-up apparatus ~~the invention described in (14)~~.

~~An optical information recording and reproducing method described in (255)~~ A two hundred fifty fifth structure of the optical information recording and reproducing method of the invention is characterized in that the optical element to vary the divergence degree or convergence degree of the incident light into the final optical element can change the refractive index distribution. The effect of such the invention is the same as in the fifteenth structure of the optical pick-up apparatus ~~the invention described in (15)~~.

~~An optical information recording and reproducing method described in (256)~~ A two hundred fifty sixth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has at least one aspherical optical surface. The effect of such the invention is the same as in the sixteenth structure of the optical pick-up apparatus ~~the invention described in (16)~~.

~~An optical information recording and reproducing method described in (257)~~ A two hundred fifty first structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system has a diffraction surface having a ring band-like diffraction structure. The effect of such the invention is the same as in the optical pick-up apparatus ~~the invention described in (17)~~.

~~An optical information recording and reproducing method described in (258)~~ A two hundred fifty eighth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is

formed of the material whose specific gravity is not larger than 2.0. The effect of such the invention is the same as in the eighteenth structure of the optical pick-up apparatus ~~the invention described in (18)~~.

~~An optical information recording and reproducing method described in (259)~~ A two hundred fifty ninth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the plastic material. The effect of such the invention is the same as in the nineteenth structure of the optical pick-up apparatus ~~the invention described in (19)~~.

~~An optical information recording and reproducing method described in (260)~~ A two hundred sixtieth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose saturation water absorption is not larger than 0.5 %. The effect of such the invention is the same as in the twentieth structure of the optical pick-up apparatus ~~the invention described in (20)~~.

~~An optical information recording and reproducing method described in (261)~~ A two hundred sixty first structure of the

optical information recording and reproducing method of the invention is characterized in that at least one optical element constituting the light converging optical system is formed of the material whose internal transmissivity at the 3 mm thickness to the light of the oscillation wavelength of the light source is not smaller than 85 %. The effect of such the invention is the same as in the twenty first structure of the optical pick-up apparatus ~~the invention described in (21)~~.

~~An optical information recording and reproducing method described in (262)~~ A two hundred sixty second structure of the optical information recording and reproducing method of the invention is characterized in that the light converging optical system has at least 2 diaphragms to regulate the image side numerical aperture in a plurality of information recording layers of the optical information recording medium. The effect of such the invention is the same as in the twenty second structure of the optical pick-up apparatus ~~the invention described in (22)~~.

~~An optical information recording and reproducing method described in (263)~~ A two hundred sixty third structure of the optical information recording and reproducing method of the invention is characterized in that at least one diaphragm of

the diaphragms is positioned between the final optical element and the optical information recording medium. The effect of such the invention is the same as in the twenty third structure of the optical pick-up apparatus ~~the invention described in (23)~~.

~~An optical information recording and reproducing method described in (264)~~ A two hundred sixty fourth structure of the optical information recording and reproducing method of the invention is characterized in that at least one optical element of the light converging optical system is formed by etching. The effect of such the invention is the same as in the twenty fourth structure of the optical pick-up apparatus ~~the invention described in (24)~~.

In the present specification, the phrase of the recording or reproducing of the information onto the information recording layer, means, when the information recording layer is structured by the layer through which the ~~light can be transmitted, and information recording surface, the information recording light is irradiated onto the~~ information recording surface through the layer through which the light can be transmitted, and the recording of the information is conducted onto that position, or the

reproducing of the information is conducted from that position.

The diffraction surface used in the present specification means that the surface of the optical element, for example, on the surface of the lens, a relief is provided, and a mode (or a surface) in (or on) which the angle of the light is changed by the diffraction, and when there is, on one optical surface, an area in which the diffraction is generated and not generated, it means the area in which the diffraction is generated. As the shape of the relief, for example, on the surface of the optical element, it is formed as an almost concentric circle-like ring band around the optical axis, and when viewing its cross section on the surface including the optical axis, it is well known that each ring band has a saw-toothed shape, and it includes such the shape. Specifically, such the saw-toothed ring band structure is preferable.

The light converging optical system used in the present specification means the optical element group to light converge the luminous flux emitted from the light source, or optical element group concerning the light convergence (for example, including a beam expander or negative lens of the aberration correction system). The final optical element

means the optical element including in the light converging optical system which is most approximate to or in contact with the optical information recording medium.

The beam expander used in the present specification means at least one optical element such as a lens is displaceable, and thereby, the divergent angle (divergent action, convergent action are included) can be changed, and when almost parallel luminous flux is incident to it, it means a collective body of optical elements such as lenses (optical element group such as lens group) from which almost parallel light can be emitted. It is preferable that a plurality of optical elements such as these lenses are integrated, and when at least the optical element such as one lens is structured to be displaceable, the drive means such as a displacing apparatus to practically displace it, may not be included as a beam expander.

In the present specification, as the optical information recording medium, it may be a disk-like medium which rotates around the center of the disk as the axis, or may not be so. Further, as the recording or reproducing system of the information onto the information recording layer, it may be a system using the phase change recording system such as a CD or DVD, or when it is a system in which

the recording or reproducing is conducted by using the converged light, it may not be limited to that.

In the present specification, the recording or reproducing of the information means that the information is recorded on the information recording surface of the optical information recording medium as described above, or the information recorded on the information recording surface is reproduced. The optical pick-up apparatus of the present invention may be used for conducting only recording or only reproducing, and may be used for conducting both of the recording and reproducing. Further, it may be used for conducting the recording onto one optical information recording medium, and conducting the reproducing onto another optical information recording medium, and it may be used for conducting the recording or reproducing onto an optical information recording medium, and conducting the recording and reproducing onto another optical information recording medium. In this connection, the reproduction used herein includes also only the reading of the information.

The optical pick-up apparatus of the present invention can be mounted onto the recording and/or reproducing apparatus of the digital data including the voice and image of each kind of player or drive, or a media equipment in

which these are assembled, personal computer, and other information devices.

(Embodiment of the invention)

Referring to the drawings, an embodiment of the invention will be described below. Fig. 2 is an outline structural view of an optical pick-up apparatus by which the recording or reproducing of the information can be conducted onto a multi-layer type optical information recording medium which is an embodiment of the present invention. In Fig. 2, the divergent angle of the information recording light emitted from the first light source 11 is changed by a coupling lens 15, and after the light passes through a beam splitter 61, the divergent angle is changed by a coupling lens 21, and after passed through an 1/4 wavelength plate 71, the light passes through a beam splitter 62, and passes through a negative lens 5 and positive lens which are displaceable in the optical axis direction, and enters into an objective lens 1 stopped down by a diaphragm 8A. In the present embodiment, the objective lens 1 is structured by the second lens 1a and the solid immersion lens 1b which is a final optical element. The information recording light emitted from the objective lens 1 is not stopped down by the diaphragm 8B arranged on the emitting surface 1b of the solid

immersion lens, and image-formed onto the first recording layer 23a of a multi-layer (in which a plurality of (herein, 2) information recording layers are provided) type optical information recording medium 23, and the information is recorded or reproduced. It is preferable that the second lens 1a of the objective lens 1 and the solid immersion lens 1b which is a SIL (Solid Immersion Lens)(or another optical element), are formed of the plastic material whose saturation water absorption is not larger than 5 %. The beam expander is structured by the negative lens 5, positive lens 6, and an actuator 7. Further, a light converging optical system is composed of the coupling lens 15, 21, negative lens 5, positive lens 6, and objective lens 1.

The light reflected by the first recording layer 23a of the optical information recording medium 23 goes the same light path, and is reflected by the beam splitter 62, and image-formed onto the light receiving surface of a light detector 41 through a cylindrical lens 9 and concave lens 16.

On the one hand, the information recording light irradiated from the second light source 12, passes through a hologram 17, and the divergent angle is changed by a coupling lens 22, and after the light passes through the 1/4 wavelength plate, it is reflected by a beam splitter 62, and

by an actuator 7, it passes the displaceable negative lens 5 and positive lens 4, and is not stopped down by the diaphragm 8A, and enters into the objective lens 1. The information recording light emitted from the objective lens 1 is image-formed onto the second recording layer 23b after it is stopped down by the diaphragm 8B arranged on the emitting surface 1b of the solid immersion lens, and the recording or reproducing of the information is conducted.

The light reflected by the second recording layer 23b of the optical information recording medium 23 passes the same light path and reflected by the beam splitter 62, and image-formed onto the light receiving surface of the light detector 42 through the 1/4 wavelength plate 72, coupling lens 22, and hologram 17 which separates the reflected light.

Herein, the interval between the solid immersion lens 1b and the optical information recording medium 23 is, as shown in Fig. 1, not larger than 1/4 of the wavelength of the information recording light. Accordingly, according to the present embodiment, by using the near field effect, the recording or reproducing of the information can be conducted onto the information recording surface of each of information recording layers, through a protective layer (not shown) of the optical information recording medium 23 by the

information recording light whose image side numerical aperture (NA) is not smaller than 1, including the evanescent light from the solid immersion lens 1b.

Further, in the present embodiment, when the negative lens 5 is moved in the optical axis direction by the actuator 7, the recording or reproducing of the information may be conducted onto the different information recording layers. Specifically, when the interval between the negative lens 5 and positive lens 6b is increased, the recording or reproducing of the information is conducted onto the information recording layer 23a nearer to the solid immersion lens 1b, and when the interval between the negative lens 5 and positive lens 6 is reduced, the recording or reproducing of the information can be conducted onto the information recording layer 23b farther from the solid immersion lens 1b. In the present embodiment, a selection means is structured by beam expanders (5, 6, 7) which function as a transfer apparatus to change the divergent angle of the luminous flux, and further, function as the optical element to change the information recording layers onto which the recording or reproducing of the information is to be conducted.

Further, in the present embodiment, corresponding to a fact that the wavelengths of the first light source 11 and

the second light source 12 are different, by using that the focal distance of the objective lens changes, the recording or reproducing of the information may be conducted onto the different information recording layers thereby. In such the case, the selection means used in the present invention means that the first light source 11, and second light source 12, and each of optical systems through which the information recording light irradiated from them passes. Such the optical system is, in the present embodiment, used as a common in a portion, however, it may be an independently separated one. However, when the optical element constituting each optical system is formed of a material whose internal transmissivity is not smaller than 85 % at the 3 mm thickness, the loss at the time of light transmission can be preferably suppressed.

In this connection, in order to selectively conducting the recording or reproducing of the information onto each of information recording layers 23a, 23 b of the optical information recording medium 23, it is considered that, for example, 2 of the second lenses 1a of the objective lens, or the solid immersion lenses 1b are prepared, and are separately used corresponding to the information recording layers onto which the recording or reproducing of the information is required to be conducted.

As a means for correcting the variation of the spherical aberration and axial chromatic aberration, when the optical surface of the second lens 1a of the objective lens 1 is formed into an aspherical surface, the aberration becomes fine, and further, when the diffraction ring band is formed on the optical surface, the axial chromatic aberration correction or the temperature correction becomes possible. However, such the aspherical surface or diffraction ring band may be provided on another optical element (the coupling lens 15, 21, 22, negative lens 5, positive lens 6).

When the negative lens 5 and positive lens 6 are used as a means for correcting the variation of the spherical aberration and axial chromatic aberration, it may be preferable when the following expression is satisfied.

$$\nu dP > \nu dN \qquad (1)$$

Particularly, it is preferable when the following expressions are satisfied.

$$\nu dP > 55 \qquad (2)$$

$$\nu dN < 35 \qquad (3)$$

Where, νdP : the average of Abbe's number of the d line of the positive lens 6, and νdN : the average of Abbe's number of the d line of the negative lens 5.

Fig. 3 is an outline structural view showing the optical system according to the second embodiment. In the present embodiment, it is different that, instead of the beam expander shown in Fig. 2, the optical element SE is used and the light converging optical system is structured. The optical system SE as the changing means is an element by which the refractive index distribution can be changed, and in Fig. 3, it is arranged on the light source (not shown) side of the solid immersion lens 1b.

The optical element SE is formed in such a manner that, as shown in Fig. 3, for example, an electrode layers a, b, and c which are electrically connected and optically transparent, and a refractive index changeable layers d, e, which are electrically insulated from the electrode layers a, b, c, and by which the refractive index distribution is changed corresponding to the applied voltage, are alternately laminated, and the optically transparent electrodes a, b, c are divided into a plurality of areas.

Herein, by using the optical element SE, to select the information recording layers of the multi-layer type optical information recording medium 23, the voltage is applied onto the electrode layers a, b, c by the drive apparatus DS of the optical element SE, and when the refractive index of the

refractive index changeable layers d, e is changed corresponding to the place, and the phase of the emitted light from the optical element SE toward the solid immersion lens 1b is controlled, the divergence degree or convergence degree of the incident light into the solid immersion lens 1b can be changed. When the divergence degree or convergence degree of the incident light into the solid immersion lens 1b is changed, the image formation position of the light which is light converged by the solid immersion lens 1b is changed, thereby, the information recording layer onto which the information is recorded or reproduced can be changed.

Fig. 4 is an outline structural view showing the optical system according to the third embodiment. In the present embodiment, the optical element SE as the changing means is provided with a liquid crystal element a' in which the liquid crystal molecule is arranged aligning in the arbitrary X direction, in the vertical surface to the optical axis, and a liquid crystal element b' in which the liquid crystal molecule is arranged aligning in the Y direction perpendicular to the X direction, in the vertical surface to the optical axis, and by the liquid crystal element a', b', the glass substrate c' is nipped, and alternately laminated,

and a 1/2 wavelength plate d' is arranged between the inside glass substrates c'.

Herein, by using the optical element SE, to select the information recording layer of the multi-layer type optical information recording medium 23, when the voltage is applied onto the liquid crystal elements a', b' by the drive apparatus DS of the optical element SE, and the X direction component and Y direction component of the phase of the emitted light from the optical element SE are independently controlled, the divergence degree or convergence degree of the incident light into the solid immersion lens 1b can be changed. When the divergence degree or convergence degree of the incident light into the solid immersion lens 1b is changed, the image formation position of the light which is light converged by the solid immersion lens 1b is changed, thereby, the information recording layer onto which the information is recorded or reproduced can be changed.

As described above, according to the optical element SE shown in Figs. 3 and 4, when the refractive index distribution is generated corresponding to the voltage impression, thereby, the layer which is an object of the recording or reproducing is changed, the light converging optical system not having movable parts and having a

mechanically simple structure can be provided. In this connection, as it is well known, by the optical element SE, the variation of the spherical aberration can also be corrected.

Fig. 5 is a view showing the relationship between the final optical element and the diaphragm, according to the fourth embodiment. As shown in Fig. 5(a), the information recording light by which the information is recorded or reproduced onto the first information recording layer 23a (Fig. 2) of the information recording layers 23 is stopped down by the diaphragm 108A arranged on the incident surface side of a single dioptric SIM (Solid Immersion Mirror, hereinafter, called SIM), 1b' as the final optical element supported through an interval not larger than 1/4 of the using wavelength to the optical information recording medium 23, and as shown in Fig 5(b), the information recording light by which the information is recorded or reproduced onto the second information recording layer 23b (Fig. 2) of the information recording layers 23 is stopped down by the diaphragm (transmission opening portion) 108B arranged between the SIM 1b' and optical information recording medium 23.

Fig. 6 is a view showing the relationship between the objective lens and the diaphragm according to the fifth embodiment. As shown in Fig. 6(a), the information recording light by which the information is recorded or reproduced onto the first information recording layer 23a (Fig. 2) of the information recording layers 23 is stopped down by the diaphragm 208A arranged on the incident surface side of the second lens 1a of the objective lens, and as shown in Fig. 5(b), the information recording light by which the information is recorded or reproduced onto the second information recording layer 23b (Fig. 2) of the information recording layers 23 is stopped down by a diaphragm (transmission opening portion) 208B arranged between the solid immersion lens 1b and the optical information recording medium 23. According to the 4 and 5 invention described above, the image side numerical aperture (NA)in the case where the information is recorded or reproduced onto each of information recording layers can be respectively independently set when the diameters of the apertures of the diaphragms 108A and 108B or 208A and 208B are adjusted.

Fig. 7 is a view showing a light converging optical system according to the sixth embodiment. The light converging optical system of the present embodiment is

structured by a SIM 1b' supported through the interval not larger than 1/4 of the using wavelength to the multi-layer type optical information recording medium 23, and a beam expander structured by respectively one positive lens 105 and one negative lens 106 from the light source side, not shown. When, from the position shown in Fig. 7(a), only the positive lens 105 of the beam expander is moved along the optical axis to the SIM 1b' side (position shown in Fig. 7(b)), the divergence degree of the incident light into the SIM 1b' is changed, thereby, the information recording layer of the optical information recording medium 23 which is an object to record or reproduce the information, is changed. In this connection, the order of the positive lens 105 and negative lens 106 is not also concerned about the order of the negative lens and positive lens from the light source.

Fig. 8 is a view showing a light converging optical system according to the seventh embodiment. The light converging optical system of the present embodiment is structured by a solid immersion lens 1b supported through the interval of 1/4 of the using wavelength to the multi-layer type optical information recording medium 23, and a beam expander structured by respectively one positive lens 205 and one negative lens 206 from the light source side, not shown.

When, from the position shown in Fig. 8(a), only the positive lens 205 of the beam expander is moved along the optical axis to the solid immersion lens 1b side (position shown in Fig. 8(b)), the divergence degree of the incident light into the solid immersion lens 1b is changed, thereby, the information recording layer of the optical information recording medium 23 which is an object to record or reproduce the information, is changed.

Fig. 9 is a view showing a light converging optical system according to the eighth embodiment. The light converging optical system of the present embodiment is structured by a solid immersion lens 1b supported through the interval of 1/4 of the using wavelength to the multi-layer type optical information recording medium 23, and a beam expander structured by the second lens 1a and diaphragm 308A, and respectively one negative lens 305 and one positive lens 306 from the light source side, not shown. When, from the position shown in Fig. 9(a), only the negative lens 305 of the beam expander is moved along the optical axis to the solid immersion lens 1b side (position shown in Fig. 9(b)), the divergence degree of the incident light into the solid immersion lens 1b is changed, thereby, the information recording layer of the optical information recording medium

23 which is an object to record or reproduce the information, is changed.

Fig. 10 is a view showing an objective lens composition according to another embodiment. In Fig. 10, the solid immersion lens 1b is a super semi-spherical lens, and structured so that the following aplanatic conditional expressions are realized. Further, the light converging point of the solid immersion lens 1b is at just an intermediate between 2 recording layers.

$$S = r(1 + (n' / n)) \qquad (4)$$

$$S' = r(1 + (n / n')) \qquad (5)$$

Where, S: the distance from the image forming point P of the second lens 1a to the apex V of the solid immersion lens 1b, S' : the distance from the image forming point P' of the composite system to the apex V of the solid immersion lens 1b, r: the radius of curvature of the solid immersion lens 1b, n: the refractive index of the air, and n' : the refractive index of the solid immersion lens 1b.

Herein, in Fig. 10, the numerical aperture (NA) of the second lens 1a is sin θ (θ is a half angle of the maximum conical angle of the image space of the objective lens), and NA' in the composition system of the objective lens composed of the second lens 1a and the solid immersion lens 1b can be

expressed by $(n')^2 \cdot \sin\theta$ (in this connection, n' is the refractive index of the solid immersion lens 1b). Further, when the aberration of the objective lens is finely corrected, this solid immersion lens 1b can realize the light convergence of almost no aberration. Accordingly, when the objective lens for the existing CD, DVD is used as the objective lens, the optical system whose image side numerical aperture (NA) is not smaller than 1, and whose aberration is finely corrected, can be easily obtained.

According to the optical pick-up apparatus and objective lens of the present invention, the large capacity of optical information recording and/or reproduction, which is more increased than the conventional one, together with both the area recording density and volume recording density of the optical information recording medium, can be conducted.